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Variation in Nacreous Color of Certain Species of Naiades Inhabiting the Upper Ohio Drainage and their Corresponding Ones in Lake Erie.

BY N. M. GRIER, PH. D.

I.—Introductory and Statement of Problem.

Perhaps the greatest amount of the systematic study of color in any animal group has been given to the birds, where the demand for a more accurate color terminology in describing the hues of plumaages eventually resulted in the Ridgeway Color Standards and Color Nomenclature, (14),—a scientific achievement apparently but little appreciated by others than ornithologists. Other types of animals, such as the Insects and even the Gastropods have been by no means neglected at least from the standpoint of variation in color pattern, but the fresh water mussels, (Naiades), so far as the writer is aware have not been the subject of any but more incidental observation.

One who has formed some acquaintance with any scientific work dealing with color nomenclature, must become impressed with the apparent glittering generalities in the specific description of shells so far as epidermal and nacreous color are concerned, but lest it be thought there exist no justification for this seeming slovliness on the part of the student of the Naiades, it need only be pointed out that in the case of birds at least, they are probably less numerous in collection, species for species, than mussel shells. Moreover, they possess a distinct advantage in that their plumage colors are usually arranged in a definite color pattern, or so associated with sexual or other characters that the ornithologist may well use them more accurately for descriptive purposes, than the conchologist can with the data he even may more laboriously collect. There has thus been a proportionate development of the

study of color as one or the other group of naturalists found essential for constructive work.

The writer's interest in the Naiades has been ecological as well as systematic. In other papers, (3, 4, 5,), dealing with the Naiades he has attempted to associate certain morphological features of the shells with the physical conditions under which they lived. A definite change of morphological features was found to parallel changes in physical conditions. Morphological features of shell are to the systematist, descriptive characters, as are also epidermal and nacreous colors. It would therefore be worth while to look for changes in the latter also to complete the idea of parallelism, and if at the same time, some progress could be made toward systematizing the color nomenclature as existing now in the Naiades so much the better—especially if such could be done with regard to any existing accepted scientific terminology, such as that of Ridgeway. With this preliminary hint of the two-fold scope of the observations to be given and the ultimate basis from which it proceeded, we pass to a digest of the literature only with which we are concerned, (the species dealt with in this paper), as it is felt that the citation of even more fragmentary observations about the other species of Naiades can add but little. At the same time, it may be pointed out that in itself the literature cited largely illustrates points which are the basis of conclusions later to be taken.

Wilson and Clark, (18–19), state that *Unio gibbosus* (*Elliptio dilatatus*), and *Lampsilis*, (*Eurynia*) *rectus* have a greater percentage of white nacre going down stream, (Maumee Drainage). Soft water and amount of humic acid in the upper waters may favor a purplish deposit, while colorless forms which occur shortly after limestone beds are reached, may be found where there is an excess of abundance of lime. . . . The rosy hue of *Quadrula coccinea*, (*Pleurobema coccineum*) seems to be of a different nature going down stream . . . the majority of this species from the Maumee are white, few with a rosy nacre. *Quadrula rubiginosa*, (*Fusconaja flava*) for the most part is white, but some are yellowish rosy. In this drainage 2-3 of *Unio gibbosus* are white. *Lampsilis rectus* had a purple nacre in some streams, white in others. In the Kankakee Drainage, (19), upstream, *Quadrula coccinea* was found to be of a delicate pink color, lower down becoming white, while all shells of Elliptio in the upper part of the Kankakee Basin are of

a deep purple color. Utterback, (16), found that the nacre of *Elliptio* was darker in upstreams sections fading out toward the mouth confirming Wilson and Clark's observation. He additionally points out that of *Quadrula verrucosa* that the pink nacred shells are confined to southern Missouri; of *Pleurobema obliquum catillus* that in the Gasconade it has a white nacre, while in the Osage River it is pink. Wilson and Clark further, (18), the color of Anodonta grandis is in ½ the cases dark purple, the other half creamy white. There may be added a curious observation of Israels on *Unio crassus*, that the epidermis of females were usually of a gray color, while that of the males were red.

Following the clues given in the foregoing, effort will be made in this paper to throw light on the following problems connected with the color of nacre in species of Naiades dealt with, viz;

I. In those species commonly assigned more than one characteristic nacre color, to determine as far as possible the relative prevalance of each color in all the shells as a whole, and the difference between L. Erie and Upper Ohio shells in this regard.

II. To determine whether any change in nacreous color takes place going down stream, both in the rivers and their tributaries, and to learn whether in any of the species, a particular shade of the described nacre color is peculiar to the bady of water concerned.

III. To associate as far as possible certain shades of the described nacre color with the sex of the animal in each of the species dealt with.

II.—List of Species Used.

LAKE ERIE	UPPER OHIO DRAINAGE
1. Fusconaja flava parvula ,Grier.	*Fusconaja flava, Raf.*
2. Amblema plicata, Say.	*Amblema costata, Raf.*
4. Pleurobema obliquum pauperculum, Simpson.	*Pleurobema obliquum coccineum, Con.*
3. Elliptio dilatatus sterkii, Grier.	*Elliptio dilatatus, Raf.*
5. Syphynota costata eriganensis, Grier	*Symphynota costata, Raf.*
6. Anodonta grandis footiana, Lea.	*Anodonta grandis, Say.*
7. Paraptera alata, Say.	*Paraptera alata, Say.*
7. Paraptera fragilis, Raf.	*Paraptera fragilis, Raf.*
8. Proptera alata, Say.	*Proptera alata, Say.*
9. Anodontoides ferrus-subcylind. Lea.	*Anodontoides ferrussacianus Leo.*
10 Eurynia recta, Lam.	*Eurynia recta latissima, Raf.*
11. Lampsilis luteola rosacea, Dekay.	*Lampsilis luteola, Lam.*
12. Lampsilis ovata conadensis, Lea.	*Lampsilis ovata ventricosa, Lam.*

The accompanying map and list of localities showing the collecting stations will give some idea of their distribution in the Upper

Ohio Drainage and Lake Erie. The material used was collected by Dr. A. E. Ortmann over a number of years, (1903-07), in Western Pennsylvania and Lake Erie, or secured by him in smaller amount as exchanges. Dr. Ortmann, besides suggesting the value of an introductory study to the color problem in Naiades, has done everything in his power to assist the investigation, for which data was obtained at the Carnegie Museum, Pittsburgh. I am also indebted to Dr. W. J. Holland, Director of the Carnegie Museum for the freest use of its facilities in connection.

III.—Physical Conditions and Type of Mussel Fauna.

The type of Mussel Fauna has already been admirably treated in papers by Walker, (17) and Ortmann, (12). These and the physical conditions concerned have already been summarized by the writer elsewhere, (5); the latter are ably given for L. Erie by Jennings (8), and for the Upper Ohio Drainage in the Water Supply papers of the U. S. Geological Survey (6). For sake of convenience, however, the outstanding points concerning the physical conditions are given in the following, contrasting columns.

LAKE ERIE	UPPER OHIO DRAINAGE
Water colder than in Upper Ohio, but with more even regulation of temperature. Currents much less rapid than in streams, less agitated, except by very moderate currents, carrying but little sediment. Bottom pebbles or sand or mixture of these, depending on region of lake, with coarser sediment derived from wear of land. Temperature conditions favor a more uniform production of food, while the water contains more lime.	*Water warmer, but greater extremes of temperature to face. Streams more rapid than current of L. Erie; greater agitation, frequent falls and rapids, short stretches of quiet pools. River carry a load of debris moving quickly over the bottom which consists of mud, glacial fill, cobbles. Food conditions, (due to extreme of temperature), are less stable, even if at times food is more abundant.*

It may be added that L. Erie shells as a whole have been observed to possess brighter (clearer) colors than their fellows of the Upper Ohio Drainage, are exceptionally polished, and otherwise characterized in distinction by their well developed lines of growth. Dr. Walker in a letter to the writer, (1914) suggested that certain depauperate qualities of the L. Erie shells may be due to the chemical quality of the water, pointing out that the influence of brackish water upon fluviatile species is well known. The relation of this fact to the color problem will be dealt with later.

IV.—Method.

As previously indicated, the nacreous color of the Naiades does not readily lend itself to the determination of any well defined color pattern. The writer therefore confined his efforts to the tabulation of the nacreous colors of each species of shell by means of comparisons with the standard colors given in the Ridgeway Color Nomenclature. Usually but one color was recorded—that one most impressing the eye with its vividness and preponderance in the nacre. Where the number of shells from a locality was small, sometimes 2-3 colors were recorded, but only if they appeared to be of equal tone in the shell. Such data was later useful in tracing genetic relationship in the sequence of color change. The color or colors judged most to match were then written in figuring books opposite calculations previously made for the morphological features of each shell. Shell were rejected when erosion of the nacre was such that no definite determination of nacre color could be made. As a rule, white as a *color* was not recognized when there existed a fair suspicion that another color was the original one, for scientifically speaking, white is a combination of colors, and usually the writer was able to refer whitish shades to pearl blue and closely similar colors.

Where a large number of shells from one locality were concerned, it was the usual practice to group all the shells of a closely similar nacre color, and compare as a whole with the shades in Ridgeway. By this means, a general or average hue was obtained, not accurate of course for every shell, but very convenient in determining the relative color of the shells at the locality to ones near it, above or below in the particular body of water. As a rule these relative colors were taken from a fairly large number of shells—8 in most cases, although lack of material often completed the use of smaller numbers. Against such treatment, however, was the check of a separate color comparison for each shell.

By means of the method above described, it was possible to determine for each species, a shade of nacre color peculiar to the locality where the shell had been collected, and this being done charts were prepared showing the sequence of color or color changes passing down stream, or the distribution in different parts of the same body of water. This data is presented in Plate III. Even by this process of condensation, a very large number of colors were obtained for each species, making it imperative to

simplify further in order that the evidence for the relative prevalence of different nacreous colors in those species where more than one was described, might be rendered more intelligible for report. Just as the systematist for roughly descriptive purposes has picked out a number of the more prominent nacreous colors of each species, the writer, largely following Simpson's Descriptive Catalogue of the Naiades(15), chose from the previously prepared charts, the 5-15 "leading colors" in the nacreous color of each species, to which the large majority of the rest could be assigned. Percentages of these leading colors were then calculated for each species in the bodies of water, drainages, groups of drainages in which they were found, as best seemed to throw light on the problems to be attacked. While all recorded shades in a large number of the species would not conform to this treatment, they represent percentages in the extreme minority. These may be inferred to exist in those species where the table on "Distribution of Colors as a Whole," does not add up to 100%. Strictly speaking, even this comparatively large number of "leading colors" could have been condensed to a smaller number, but a larger number was necessary in order that certain close distinction in the color of nacre for purposes of the investigation might be made, for example, between the color of shells of a river and those of its tributaries. In the discussion of any particular body of water, however, when the latter is considered by itself, the leading colors given represent my reduction to lowest terms. of the colors represented in it.

V.—Results.

Each species is dealt with separately, there first being given in parallel columns,

(a) Descriptive material concerning the nacreous color as taken from Simpson (15).

(b) The equivalent in the writer's opinion of the Simpson colors in terms of the Ridgeway Color Nomenclature.

It is felt that by this arrangement, and the inferences to be drawn from the names of the Ridgeway Colors themselves, it will be possible for the reader to sufficiently understand the terminology used as to convey the principles this paper hopes to make clear. For the sake of even greater clarity, there are also given latterly in the Ridgeway column, the peculiar shades of the Lake Erie shells, although these are, by the convenient arbitracy

arrangement adopted, but varieties of the hues given in the tables, on "Distribution of Colors as a Whole in the latter of which, effort is made to throw light on the first problem stated. There then follows tables of percentages giving the relative distribution of colors in the Upper Ohio Drainage as a whole, and separately, its component drainages. The same is done for Lake Erie and its various collecting stations. After remarks largely in explanation of outstanding points of Plate III, (chart illustrating sequence of nacreous color changes; Problem III, the discussion of each species terminates with the evidence for possible association of Sex Correlative Coloration with the nacreous color of the shell.

1.—*Fusconaja flava.*

SIMPSON	RIDGEWAY
White to Salmon;	Pearl blue, Pale Grayish Blue Violet, Pale Medici Blue Pale Pinkish Cinnamon, Pale Pinkish Buff, Light Flesh Pink.
Rose tinted.	Light Orange Pink, Light Salmon Orange.

Distribution of Colors as a Whole in Upper Ohio Drainage and L. Erie. (273 shells.)

Pale Pinkish Cinnamon and allied colors	21%
Pale Pinkish Buff and allied colors	13%
Light Orange Pink and allied colors	11%
Pale Grayish Blue Violet and allied colors	25%
Pearl Blue and allied colors	10%

Distribution of Colors as a Whole in Upper Ohio Drainage. (225 shells)

Pale Pinkish Cinnamon and allied colors	27%
Pale Pinkish Buff and allied colors	23%
Light Orange Pink and allied colors	16%
Pale Grayish Blue Violet and allied colors	17%

Distribution of Colors as a Whole in Upper Ohio Tributaries, etc.

	Alle'ny Tribs.	*Alle'ny River*	*Mon'g. Tribs*	*Mon'g. River*	*Ohio Tribs.*	*Ohio River*	*Tusca. River*
Pale Pink. Cinnamon, etc	30%		62%	27%	100%	30%	
Pale Pink. Buff, etc	25%	67%		23%		25%	50%
Light Orange Pink, etc.	20%			50%		20%	
Pale Gray. Blue Violet, etc	13%	33%					50%
Pale Gray Lavender, etc			25%				
Deeper Hermosa Pink						25%	

Distribution of Colors as a Whole in L. Erie. (67 shells).

Pearl Blue and allied colors	18%
Light Flesh Pink and allied colors	18%
Pale Gray. Blue Violet and allied colors	14%

Pale Medici Blue and allied colors.....14%
Light Salmon Orange and allied colors.....14%

Distribution in L. Erie—localities.

	La Plaisance Bay	*Cedar Point*	*Presque Isle Bay*
Pearl Blue and allied colors	12%		
Light Salmon Orange and allied colors	25%	67%	14%
Light Gray. Blue Viol. and allied colors	50%		33%
Medici Blue and allied colors		33%	
Light Flesh Pink and allied colors			33%
Light Buff			8%

Deductions from Tables of Percentages and Plate III:

It will be immediately noted that bluish colors are more prominent in L. Erie than in the Upper Ohio Drainage. Reddish colors also tend to have lighter hues in the former. Colors of a buffy or orange tone rather than pinkish, are most abundant in rivers, where grayish colors also seem to predominate. The intensity of the nacre color seems to diminish in the river especially going down stream. Exceptions to this are in the minority.

In the Upper Ohio Drainage:

In Crooked Creek, Creekside, the shells are mainly light grayish blue violet, but lower down at Rosston, are of a light salmon, fading at a near station on Allegheny River, Kelly, to pale salmon. A progressive fading out may be traced down the latter stream, as well as in a tributary of the Mononghela, Dunkard Creek. The shells of the Monongahela at this point are much like those of Dunkard Cr. but not as red, (pale pinkish cinnamon). As the Ohio is approached, the nacre becomes yellowish, (pale pinkish buff), and finally fades to grayish hues. In 10 mi. Cr. at Amity, the shells take on a grayish lilac hue, but at Clarksville this becomes considerably lightened to reddish colors. In Raccoon Cr. this species has a nacre color of reddish pink, at the nearest collecting point in Ohio it has a yellow tinge.

In Lake Erie:

Presque Isle is characterized by greater proportions of salmon colors. La Plaisance Bay by those of a bluish caste, Cedar Point, orange. In this, as well as other species, different parts of the

* I found no strickly pure white in this species. It seemed practically negligible or is represented in the lighter allied colors of Pale Grayish Blue Violet.

same collecting locality—such as the various stations at Presque Isle, are apt to show a peculiarly distinctive nacreous color.

Observation on Sex Correlative Coloration as Associated with Nacreous Color. (27 Shells).*

Blues and Allied colors are twice as numerous in males than in females. Females appear to have the more vivid pinks, while those males even approximating the latter colors have reddish hues.

2.—Amblema Plicata

In this species, particular attention was paid to the prevailing hue of the iridescence at the posterior end, as the rest of the shell is whitish. The rusty spots common in this species were ignored.

SIMPSON	RIDGEWAY
Iridescence—Bluish	Pearl Blue, Grayish Lavender, Pale Verbena Violet Pale Vinaceous, Pale Salmon, White.

Distribution of Colors as a Whole in Upper Ohio Drainage and Lake Erie. (185 shells).

Pearl Blue and allied colors	44%
Grayish Lavender and allied colors	22%
Pale Vinaceous and allied colors	30%
White	4%

Distribution of Colors as a Whole in Upper Ohio Drainage (107 shells).

Pearl Blue and allied colors	45%
Grayish Lavender and allied colors	19%
Pale Vinaceous and allied colors	36%

Distribution of Colors as a Whole in Upper Ohio Tributaries, etc.

	Alle'ny Tribs.	*Alle'ny River*	*Beaver Tribs.*	*Beaver River*	*Ohio River*
Pearl Blue and allied colors	50%	55%	20%	50%	33%
Gray. Lavender and allied colors	18%	22%	23%		
Pale Vinaceous and allied colors	33%	22%	55%	50%	66%

Distribution of Colors as a Whole in L. Erie. (78 shells).

Pearl Blue and allied colors	50%
Pale Verbena Violet and allied colors	33%
Gray, Lavender and allied colors	11%
Pale Salmon	6%

* The small number of shells on which this and similar observations for other species is due to the fact that most of the shells were collected before Ortmann's discovery that the sex of these animals is readily determined from cell structure.

Distribution in Lake Erie—Localities.

	Presque Isle Bay	*Cedar Point*	*La Plaisance Bay*
Pearl Blue and allied colors	57%	100%	20%
Pale Ver. Violet and allied colors	37%		
Light Pink. Viol. and allied colors			80%
Pale Salmon and allied colors	6%		

Deductions from Tables of Percentages and Plate III.

Pearl blue is most largely represented in Lake Erie. Colors in the Upper Ohio tend to be grayish in nature, those corresponding in L. Erie, more of a violet.

In the Upper Ohio Drainage:

Pearl blue is more prominent in the Allegheny River than in its tributaries, and is more abundant in the Beaver than in the Allegheny. The nacreous color apparently tends to acquire deeper tones in the lower stretches of both the Allegheny and the Shenago. Altho' pearl blue is recorded at its lowest station, grayish lavender would be a composite shade characterizing shells from French Creek, where the pale verbena violet of the upper stretches fades to pearl blue lower down. A similar fading is seen in the Shenango, whose shells are more of a blue compared with its sister river, the Mahoning, where they tend to take on a lilac tinge. Perhaps shells really coming from the Mahoning were the ones of this species obtained in the Beaver River. In Slippery Rock Creek, the shells are pearl blue, in the Ohio River, pale grayish vinaceous.

In Lake Erie:

A bluish violet color characterizes the shells obtained at Cedar Point. This shade accompanied by pinkish violet is distinctive for Presque Isle, while pinkish violets are in the great majority at La Plaisance Bay. Examination of Pl. III shows more fully the variability at Presque Isle.

Observation on Sex Correlative Coloration as Associated with Nacreous Color. (19 shells).

Females appear to be prevailingly pearl blue, while the males are characterized by pale vinaceous colors. The amount of grayish lavender represented is equivalent in both.

3.—*Elliptio dilatatus*

SIMPSON	RIDGEWAY
Deep purple.	Light Vinaceous Lilac, Light Vinaceous Purple, Deep Vinaceous, Deep Vinaceous

	Lavender, Deep Vinaceous Gray, Dark Vinaceous Gray.
Salmon, Straw colored	Pale Ochraceous Buff.
White*	Pearl Blue, white.

Distribution of Colors as a Whole in Upper Ohio Drainage and Lake Erie. (561 shells).

Pearl Blue with allied colors	18%
Light Vinaceous Lilac and allied colors	28%
Light Vinaceous Purple and allied colors	27%
Deep Vinaceous Gray and allied colors	20%
Pale Ochraceous Buff and allied colors	05%

Distribution of Colors as a Whole in Upper Ohio Drainage (509 shells).

Pearl Blue and allied colors	11%
Light Vinaceous Lilac and allied colors	22%
Light Vinaceous Purple and allied colors	25%
Purple Drab and allied colors	12%
Pale Ochraceous Buff and allied colors	6%

Distribution of Colors in Upper Ohio Tributaries, etc.

	Alle'ny Tribs.	*Alle'ny River*	*Mon'g Tribs.*	*Mon'g River*	*Ohio Tribs.*	*Ohio River*	*Beaver Tribs.*	*Beaver River*
Pearl Blue, etc.	9%	11%	13%	14%	6%	14%	6%	
Light Vin. Lilac, etc.	17%	42%	27%	33%	41%	56%	21%	39%
Light Vin. Purple, etc.	37%	35%	14%	60%	36%	30%	50%	11%
Light Purple Drab	7%	12%	46%	3%	6%		10%	24%

Distribution of Colors as a Whole in L. Erie. (52 shells).

Light Vinaceous Purple and allied colors	27%
Deep Vinaceous Lavender and allied colors	30%
Deep Vinaceous Gray and allied colors	23%
Dark Vinaceous Gray and allied colors	18%

Distribution in Lake Erie—Localities.

	Presque Isle	*La Plaisance Bay*
Light Vinaceous Purple	20%	20%
Deep Vinaceous Lavender	36%	10%
Deep Vinaceous Gray	36%	50%
Dark Vinaceous Gray	10%	20%

Deductions from Tables of Percentages and Pl. III.

Although pearl blue is represented in L. Erie, the percentage seems small. The colors of the Upper Ohio Drainage seem to be more of a purple lilac, while those of L. Erie are more of a lavender gray. There is at least a distinct lightening of nacreous color in Lake Erie.

*White was found to occur less than 1% in all the shells examined.

In the Upper Ohio Drainage:

As a general thing the colors are lighter in the rivers than in the tributaries. This species is exceedingly variable with regard to nacre color. A general tendency to lighten in color may be observed coming down the Allegheny thus confirming Wilson and Clark's and Utterback's observations. It is true, however that at certain stations it appears to darken, but this result is from a small number of shells. Such apparently also occurs in French Creek, but the shells of the Allegheny are lighter than those of French Creek at the nearest collecting point. Pearl blue is largely limited to the Allegheny River and its tributaries. Nacreous colors, are lighter in the Monogahela than in its tributary, the Cheat. They also tend to lighten in the Ohio River, but in the Shenango at the headwaters they are deep vinaceous, (reddish purple), in hue, lower down becoming more purplish. Characteristic Stream Colors appear to be,

Purple drab for Potato Cr.

Light Purple Drab for Sandy Cr.

Vinaceous colors for Cheat River.

Light Vinaceous Purple drab in Neshannock Cr.

Light reddish to light purples in the Mahoning, lower down becoming purplish lilac to slate purple.

Vinaceous Gray is characteristic of the Ohio.

In Lake Erie:

Presque Isle stands out for its large amount of reddish purple shades, while La Plaisance Bay has grayish purple ones. The great variability of Presque Isle shells may again be noted. Those from other L. Erie localities than those given in L. Erie are so small that *percentages* are not given.

In Chautauqua Lake the shells appear to be mainly white.

Observation on Sex Correlative Coloration, etc. (15 shells).

More males have a pearl blue nacre than females. They also have a larger percentage of lilac shades. Females seem to be characterized by a deeper purple color, and a greater number of lilac shades.

4.—*Pleurobema obliquum coccineum*

SIMPSON	RIDGEWAY
Rose-Pink	Pale Vinaceous Pink, Light Ochraceous Salmon, Orange Pink.
Whitish-red*	Pearl Blue, Venetian Pink, Light Pearl Blue, Burn Blue

* Pure whites appear to be negligible among the shells I examined.

Distribution of Colors as a Whole in Upper Ohio Drainage and L. Erie. (263 shells).

Pearl Blue and allied colors	44%
Pale Vinaceous Pink and allied colors	18%
Venetian Pink and allied colors	20%
Light Ochraceous Salmon and allied colors	8%

Distribution of Colors in Upper Ohio Drainage (247 shells).

Pearl Blue with allied colors	48%
Venetian Pink with allied colors	30%
Pale Vinaceous Pink and allied colors	14%
Light Ochraceous Salmon and allied colors	8%

Distribution of Colors in Upper Ohio Tributaries etc.

	Alle'ny Tribs.	*Alle'ny River*	*Beaver Tribs.*	*Beaver River*
Pearl Blue and allied colors	63%	27%	30%	46%
Venetian Pink and allied colors	10%	33%	31%	38%
Pale Vinaceous Pink and all col	7%	19%	13%	
Light Ochraceous Salmon & all col	14%	11%	20%	15%

Distribution of Colors as a Whole in L. Erie.

Pale Vinaceous Pink and allied colors	45%
Burn Blue and allied colors	33%
Orange Pink and allied colors	16%
Light Pearl Blue and allied colors	4%

Distribution in L. Erie—Localities.

	Presque Isle Bay	*La Plaisance Bay*
Pale Vinaceous Pink, etc	66%	
Burn Blue, etc		88%
Orange Pink, etc	14%	
Light Pearl Blue, etc	11%	

Deductions from Tables of Percentages and Pl. III.

Pearl blue as such is more abundant in the Upper Ohio Drainage, but to explain this apparent discrepancy to the tendencies already observed, it may be pointed out that there are larger percentages of *bluish* colors in L. Erie than in the Upper Ohio, furthermore the more or less lilac shades of L. Erie shells show admixture with bluish tints.

In the Upper Ohio Drainage:

Pearl blues are found to greater extent in the rivers than in their tributaries, where the colors are pink and reddish. Fading out tendencies are observed in the Allegheny River and French Creek. At the nearest station to the Allegheny River in French Creek they are pinkish, while in the Allegheny itself they are grayish blue.

Characteristic stream colors appear to be,

Pearl blue in the Loyalhanna, altho' a few are pink.

Pinks and blues are apparently equal in the Shenango, altho' these colors are seen to merge to a light grayish blue violet, the pinks fading out.

Pale flesh color in the Pymatuning with a scattering of deeper blues, (Plumbago blue).

Pinks and blues seem equally distributed in Neshannock Creek.

Pinkish colors in Slippery Rock Creek.

In L. Erie

Lilac colors are characteristic at Presque Isle, Burn Blue at La Plaisance Bay.

Observation on Sex Correlative Coloration, etc. (15 shells).

Males possess more pearl blues, less salmon colors, and a tendency toward lilac colors not found in females. The latter have a preponderance of vivid pinks.

5.—*Symphynota (Lasmigona) costata.*

Here closest attention was paid to the color of the nacre in the umbonal cavity, as apparently being the most variable.

SIMPSON	RIDGEWAY
Whitish*	Pearl Blue
Straw colored	Pale Pinkish Buff, Pale Ochraceous Buff.
	Sea-shell Pink, Pale Ochraceous Salmon
	Light Buff, Pale Pinkish Buff.

Distribution of Colors as a Whole in Upper Ohio Drainage and L. Erie. (68 shells).

Pale Pinkish Buff, etc.	27%
Pale Ochraceous Buff, etc.	23%
Sea shell Pink, etc.	16%
Pearl Blue	16%

Distribution of Colors as a Whole in Upper Ohio Drainage and L. Erie. (47 shells.)

Pale Pinkish Buff, etc.	36%
Pearl Blue, etc.	23%
Sea Shell Pink, etc.	17%
Pale Pinkish Cinnamon, etc.	10%
Pale Grayish Vinaceous	4%
Pinkish Buff	10%

*"Whitish" practically negligible in any part of the shell. Pearl Blue is probably the real shade.

Distribution of Colors in Upper Ohio Tributaries, etc.

	Allegheny Tribs.	*Allegheny River*	*Beaver Tribs.*
Pale Pinkish Buff, etc	10%	17%	28%
Pearl Blue, etc	20%	8%	14%
Sea Shell Pink, etc	10%	17%	8%
Pale Pink Cinnamon, etc	15%	17%	14%
Pinkish Buff, etc	10%	8%	
Pale Salmon, etc	10%		21%
Pale Ochraceous Buff	10%		21%
Ochraceous Buff	10%		
Light Grayish Blue Violet, etc		8%	
Pale Grayish Vinaceous, etc		8%	
Salmon Buff		8%	

Distribution of Colors as a Whole in L. Erie. (21 shells).

Pale Ochraceous Buff, etc	34%
Pale Ochraceous Salmon, etc	38%
Light Buff, etc	9%
Pale Pinkish Buff, etc	19%

Distribution in L. Erie—Localities

	Presque Isle	*La Plaisance Bay*
Pale Ochraceous Buff, etc	33%	
Pale Ochraceous Salmon, etc	33%	
Light Buff, etc		50%
Pale Pinkish Buff, etc	11%	
Pale Salmon, etc	11%	50%
Pale Cinnamon Pink, etc	11%	
Pinkish Buff, etc	11%	

Deductions from Tables of Percentages and Pl. III.

As previously noted, the greatest attention was paid in this species to the color of the umbonal cavity. Shell for shell, the blues seemed deeper in the rest of the nacre in L. Erie. altho' more pearl blue as a color of the umbonal cavity is reported from the Upper Ohio. Buff and salmon colors preponderate in L. Erie, where in the Upper Ohio, the colors may be pearl blue or pinkish.

In the Upper Ohio Drainage:

Shells lose their buff colors and become pink going down the Allegheny. This also occurs in French Creek, and seems to be the case also in the Monongahela River and possibly in the Shenango. As a general rule there seemed to be more purely pearl blue in the Allegheny Tribs. than in the river itself. Other characteristic stream colors, besides those shown on Pl. IIII are,

Ochraceous Buff in Quemahoning Cr.

Pale Pinkish Buff in French Cr.
Pale Pinkish Buff in Mahoning River.
Sea-shell Pink in Racoon Cr.

In Lake Erie:

Presque Isle apparently has a larger proportion of Salmon colors than La Plaisance Bay.

Observation on Sex Correlative Coloration, etc. (5 shells).

Pearl Blue preponderates in males.
Females have redder colors, with a large proportion of Buff.

6.—*Anodonta grandis.*

SIMPSON	RIDGEWAY.
Bluish White	Pearl Blue, Pale Grayish Blue Violet
Tinted with Purple	Vinaceous Pink, Pale Aniline Lilac.
Cream Color	Pale Pinkish Buff.

Distribution of Colors as a Whole in Upper Ohio Drainage and L. Erie. (119 shells).

Pearl Blue, etc.	40%
Pale Grayish Blue Violet	15%
Pale Pinkish Buff	33%
Vinaceous Pink	5%

Distribution of Colors as a Whole in Upper Ohio Drainage. (97 shells.)

Pearl Blue, etc.	46%
Pale Grayish Blue Violet, etc.	24%
Pale Pinkish Buff, etc.	8%
Vinaceous Pink, etc.	10%

Distribution in Upper Ohio Tributaries.

	Allegheng Tribs.	*Beaver Tribs.*	*Mgnong. River*	*Tuscarawas River*
Pearl Blue, etc.	43%	25%	100%	100%
Pale Grayish Blue Violet, etc.	33%	50%		
Pale Pinkish Buff, etc.	21%	25%		

Distribution of Colors as a Whole in L. Erie. (22 shells.)

Pearl Blue, etc.	55%
Pale Pinkish Buff, etc.	15%
Pale Grayish Blue Violet, etc.	20%
Pale Aniline Lilac, etc.	10%

Deduction from Tables of Percentages and Pl. IIII.

Pearl blue has a proportionally larger representation in L. Erie than in the Upper Ohio. L. Erie has additionally more pinkish and

buff colors. Lavenders and grays predominate in the Upper Ohio Drainage.

In the Upper Ohio Drainage:

In the headwaters of French Creek this shell is pearl blue, lower down becoming pale grayish blue violet. In the Shenango, it fades out from a pale pinkish cinnamon color in upstream regions to pale grayish blue violet downstream. Fading out is also observed in the Crooked Creek Drainage. Characteristic stream colors are,

Sea-shell pink in the Mahoning. Pearl blue in Slippery Rock and Racoon Creeks, Vinaceous pink in Sugar Creek, Pearl Blue in Tuscarawas River, Pale Grayish Blue Violet in the Maumee Drainage.

Shells from Conneaut Lake resemble those of L. Erie to some extent in possessing a light pinkish lilac hue.

In L. Erie:

Characteristic hues as shown.

Observation on Sex Correlative Coloration, etc. (8 shells).

Males have a pearl blue or cream color.

Females—pale grayish blue violet or pinkish.

7.—*Paraptera fragilis*

SIMPSON	RIDGEWAY
Faint Purplish Bluish	Pale Pinkish Lilac, Pale Congo Pink Pearl Blue.

Distribution of Colors as a Whole in Upper Ohio Drainage and L. Erie. (58 shells).

Pearl Blue, etc.	20%
Pale Pinkish Lilac, etc.	50%
Pale Congo Pink, etc.	30%

Distribution of Colors as a Whole in the Upper Ohio Drainage (28 shells).

Pearl Blue, etc.	20%
Pale Pinkish Lilac, etc.	40%
Pale Congo Pink, etc.	40%

Distribution in Upper Ohio Tribs., etc.

	Allegheny River	*Ohio River*
Pearl Blue, etc.	10%	15%
Pale Pinkish Lilac, etc.		55%
Pale Congo Pink, etc.	90%	30%

Distribution of Colors as a Whole in L. Erie (30 shells).

Pearl Blue, etc.	33%
Pale Pinkish Lilac, etc.	41%
Pale Congo Pink, etc.	20%

Distribution in L. Erie—Localities.

	Presque Isle	*La Plaisance Bay*
Pearl Blue, etc.	30%	16%
Pale Pinkish Lilac, etc.	50%	50%
Pale Congo Pink, etc.	13%	33%

Deductions from Tables of Percentages and Plate III.

There is a greater percentage of pearl blue in L. Erie, and there are more reddish shells in the Upper Ohio Drainage.

In the Upper Ohio Drainage:

Less Pearl Blue and more of the reddish colors are present in the Allegheny River. Shades tending toward purplish predominate in the Ohio. Shells of this species lighten in color going down the Allegheny and Ohio, at least in the upper stretches of the latter.

In Lake Erie:

Presque Isle possesses more pearl blues and less pink than La Plaisance Bay.

Observation on Sex Correlative Coloration, etc. (5 shells).

The males appear to have lighter lilac and pinkish shades.

8.—*Proptera alata*

SIMPSON	RIDGEWAY
Coppery purple.	Hydrangea Pink, Light Pinkish Lilac, Light Purplish Vinaceous, Light Russet Vinaceous, Light Purplish Lilac.

Distribution of Color in Upper Ohio Drainage and Lake Erie as a Whole. (55 shells).

Hydrangea Pink, etc.	27%
Light Pinkish Lilac, etc.	34%
Light Purplish Vinaceous, etc.	21%
Light Russet Vinaceous, etc.	16%

Distribution of Colors as a Whole in Upper Ohio Drainage. (24 shells).

Hydrangea Pink, etc.	27%
Light Purplish Vinaceous, etc.	46%
Light Russet Vinaceous, etc.	24%
Light Pinkish Lilac	3%


LAKE ERIE
PRESQUE ISLE
ERIE
NEW YORK
Bemus Point
Celeron
CHAUTAUQUA LAKE
Niles Grove
ELK Creek
Lake LeBoeuf
Conneaut Cr
West Springfield
Conneautte Lake
Conneautte Cr
Cambridge Springs
Russell
Larabee
Potato Cr
Smethport
Garland
Brokenstraw Cr
Hickory
WARREN
Conneaut Lake
MEADVILLE
French Cr
Tionesta
Linesville
Pymatuning Cr
Randolph Run
Hartstown
Cochranton
Cooperstown
Utica
Sugar Cr
Jamestown
Greenville
FRANKLIN
Walnut Bend
Shenango
Clarksville
Sandy Lake
Sandy Cr
Clarion River
Otter Cr
Sharpsville
Shenango R
Harbor Bridge
Hannock Cr
Leesburg
East brook
PENNSYLVANIA
Parkers Lag
Red Bank Cr
Hillsville
Pulaski
Little Mahoning Cr
Goodville
Templeton
Connoquenessing
Mosgrove
Harmony
Wurtemburg
Warrenum
Ellwood City
Zelienople
Crooked Cr
Darlington
Connelton
OHIO

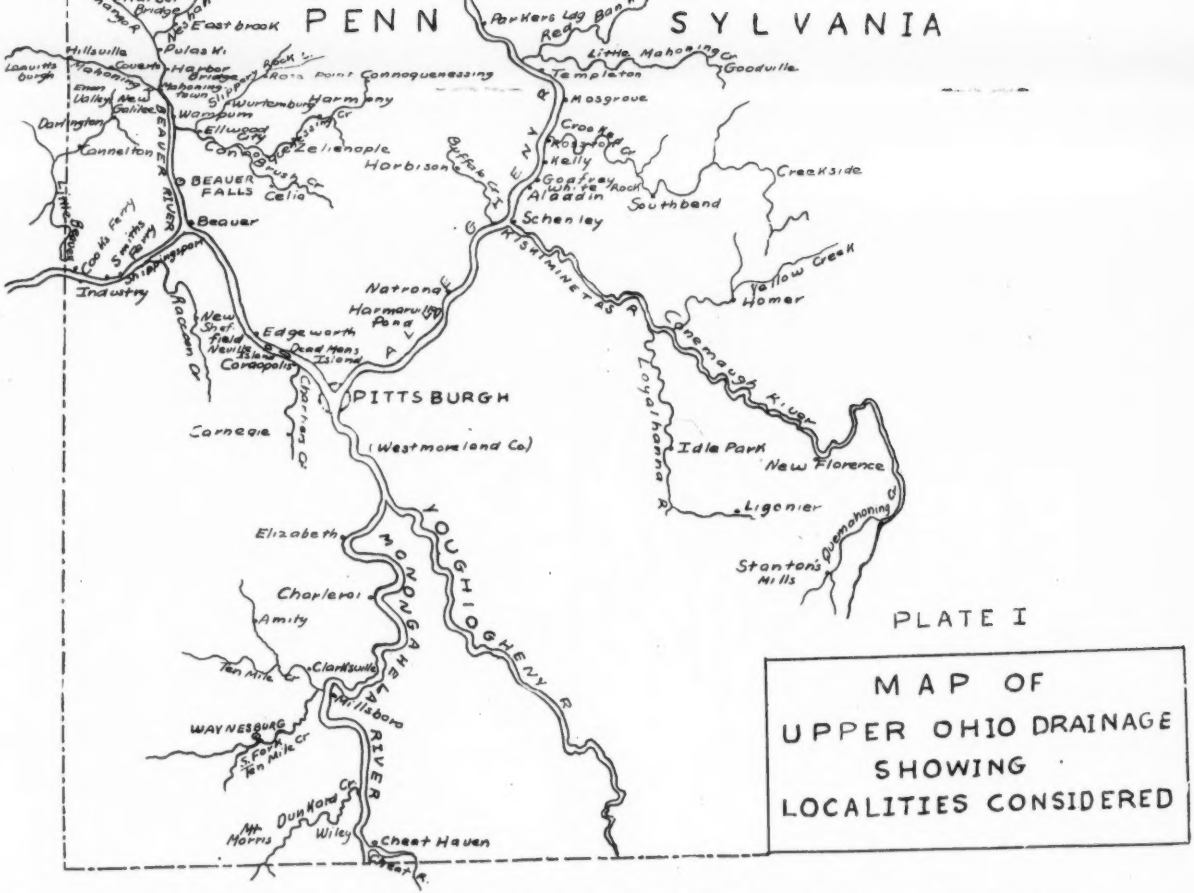

PLATE I.—GRIER ON VARIATION IN NACREOUS COLOR OF CERTAIN SPECIES OF NAIADES.

Distribution in Upper Ohio Tributaries.

	Alle'ny Riv	*Monong. Riv.*	*Ohio Riv.*
Light Purplish Vinaceous, etc.	60%	60%	33%
Light Russet Vinaceous, etc.	30%	40%	33%
Hydrangea Pink, etc.	10%		33%

Distribution of Colors as a Whole in L. Erie (31 shells).

Hydrangea Pink, etc.	25%
Light Purplish Lilac, etc.	50%
Grayish Vinaceous, etc.	25%

Distribution in L. Erie—Localities.

	La Plaisance Bay	*Cedar Point*	*Presque Isle*
Hydrangea Pink, etc.	67%	16%	12%
Light Purplish Vinaceous, etc.	33%	11%	44%
Light Purplish Lilac, etc.		58%	44%

Deductions from Tables of Percentages and Pl. III.

Lake Erie shells appear to be of a more uniform lilac hue, while there is a greater proportion of pinks and purples in the Upper Ohio Drainage.

In the Upper Ohio Drainage:

The nacreous color seems to be lighter in the Ohio than either the Allegheny or the Monongahela. Coppery purple, (Light Russet Vinaceous), is most prominent in the Monongahela. A tendency to lighten going down stream is seen in the Allegheny.

In Lake Erie:

La Plaisance Bay stands out for a greater proportion of pinks, Cedar Point for Lilac purple, and Presque Isle for dark purple colors.

Observation on Sex Correlative Coloration, etc. (6 shells).

Males—pinkish or lilac.

Females—purple or russet.

9.—*Anodontoides ferrussacianus.*

Here the general tone of the nacre color—not merely the iridescence—was considered.

SIMPSON	RIDGEWAY
Bluish-white	Lavender, Grayish Blue Violet, Pale Grayish Blue Violet
Bluish	Pearl Blue, Pale Aniline Lilac.

Distribution of Colors as a Whole in the Upper Ohio Drainage and Lake Erie. (69 shells).

Pale Aniline Lilac, etc.	26%

Pearl Blue, etc.	25%
Lavender, etc.	23%
Grayish Blue Violet, etc.	22%

Distribution of Colors as a Whole in the Upper Ohio Drainage. (45 shells).

Pearl Blue, etc.	23%
Pale Aniline Lilac, etc.	20%
Lavender, etc.	22%
Light Grayish Blue Violet, etc.	28%

Distribution of Colors in the Upper Ohio Tribs., etc.

	Allegheny Tribs.	*Beaver Tribs.*
Pearl Blue, etc.	14%	20%
Pale Aniline Lilac, etc.	57%	15%
Lavender, etc.		25%
Light Grayish Blue Violet, etc.	29%	40%

Distribution of Colors as a Whole in Lake Erie. (24 shells)

Pale Aniline Lilac, etc.	31%
Pearl Blue, etc.	25%
Pale Grayish Blue Violet, etc.	19%
Lavender, etc.	25%

Distribution in L. Erie—Localities.

	Presque River	*Maumee River*	*Conneaut Creek*
Pale Aniline Lilac, etc.	33%	25%	28%
Pale Blue, etc.	25%	25%	14%
Pale Grayish Blue Violet, etc.	23%	20%	43%
Lavender, etc.	15%	25%	14%

Deductions from Tables of Percentages and Pl. III.

There are more pearl blue, lilac and their related colors in L. Erie than in the Upper Ohio Drainage, but there are less of a lavender hue.

In the Upper Ohio Drainage:

Lilac colors appear to predominate in the Allegheny Tributaries as against lavender in the Beaver Tribs. Conneaut Creek draining into L. Erie possesses more pearl blue shells than either the Beaver, Shenango, or Allegheny Rivers. Descending French Creek, the nacre of the species appears to lighten. Pale grayish Blue Violet is characteristic of the French Creek, while Pearl Blue is more typical of the Shenango.

In Lake Erie:

Presque Isle stands out for lilac colors; the Maumee River which drains into it, possesses a great deal of lavender.

Observation on Sex Correlative Coloration, etc. (3 shells).

Males tend toward lavender colors, females blue. In this species, as well as a few others dealt with, the numbers used hardly justify any definite conclusion as to the association of nacreous color with the sex of the animal.

10.—*Eurynia recta.*

SIMPSON	RIDGEWAY
Purple	Light Pinkish Lilac, Light Purplish Vinaceous, Pale Congo Pink.
Bluish White	Pearl Blue
Whitish	White

Distribution of Colors as a Whole in the Upper Ohio Drainage and Lake Erie. (54 shells).

Pearl Blue, etc.	33%
White, etc.	21%
Light Pinkish Lilac, etc.	30%
Light Purplish Vinaceous, etc.	15%

Distribution of Colors as a Whole in the Upper Ohio Drainage (33 shells).

Pearl Blue, etc.	32%
White, etc.	24%
Light Pinkish Lilac, etc.	23%
Light Purplish Vinaceous, etc.	21%

Distribution of Colors in Upper Ohio Tributaries, etc.

	Alleghney Tribs.	*Alleghney River*	*Ohio River*	*Tuscarawas River*
Pearl Blue, etc.	34%	31%	36%	60%
White, etc.	16%	24%	36%	
Light Pinkish Lilac, etc.	37%	20%	16%	20%
Light Purplish Vinaceous, etc.	17%	25%	12%	20%

Distribution of Colors as a Whole in Lake Erie. (21 shells).

Pearl Blue, etc.	39%
Light Pinkish Lilac, etc.	30%
Light Purplish Vinaceous, etc.	21%
Pale Congo Pink, etc.	12%

Distribution in Lake Erie—Localities.

	Cedar Point	*Pesque Isle*
Pearl Blue, etc.	50%	36%
Light Pinkish Lilac, etc.	33%	34%
Light Purplish Vinaceous, etc.	17%	20%
Pale Congo Pink, etc.		10%

Deductions from Tables of Percentages and Pl. III.

A greater amount of Pearl blue and light purple exists in Lake

Erie. White, in any abundance, is found most in the Upper Ohio Drainage.

In the Upper Ohio Drainage:

Pinkish colors predominate in the Allegheny Tributaries, white pearl blue in the river. The Ohio and Tuscarawas Rivers show the greatest percentage of Pearl Blue. A fading out is seen descending the Allegheny. Characteristic stream colors are,

Light Pinkish Lilac in the Allegheny. White in the Ohio.

In Lake Erie:

Where Cedar Point possesses more pearl blue, Presque Isle has more pinkish and purplish colors.

In Chautauqua Lake the prevailing color is a vinaceous pink.

Observation on Sex Correlative Coloration, etc. (33 shells).

The nacre of the males seems to be prevailingly purplish; that of the females, pinkish. Pearl Blue is about evenly represented in both sexes.

11.—*Lampsilis luteola*

SIMPSON	RIDGEWAY.
Blue	Pearl Blue
Bluish White	Pale Grayish Blue Violet, White
Straw Colored, Pink	Light Pinkish Lilac, Pale Rhodonite Pink.

Distribution of Colors as a Whole in the Upper Lhio Drainage and Lake Erie (289 shells).

Light Pinkish Lilac, etc	35%
Pearl Blue, etc	13%
White, etc	17%
Pale Grayish Blue Violet, etc	35%

Distribution of Colors as a Whole in Upper Lhio Drainage (187 shells).

Light Pinkish Lilac, etc	30%
White, etc	14%
Pearl Blue, etc	24%
Pale Grayish Blue Violet, etc	35%

Distributixn in Upper Lhio Tribs., etc.

	Alle'ny Tribs.	*Alle'ny River*	*Monong. Tribs.*	*Monong River*	*Ohio River*	*Beaver Drainage*
Light Pinkish Lilac, etc	43%	40%	50%	60%	50%	42%
Pale Grayish Blue Violet, etc	14%	30%	50%			31%
Pearl Blue, etc	16%	30%			15%	13%
White, etc	27%			40%	35%	14%

Distribution of Colors as a Whole in Lake Erie (111 shells).

Pearl Blue, etc.	41%
White, etc.	20%
Light Pinkish Lilac, etc.	27%
Pale Rhodonite Pink, etc.	12%

Distribution in Lake Erie—Localities.

	La Plaisance Bay	*Cedar Point*	*Presque Isle*	*Maumee Drainage*
Pearl Blue, etc.	10%	20%	23%	20%
White, etc.	33%	3%	20%	16%
Light Pinkish Lilac	50%	25%	35%	33%
Pale Rhodonite Pink, etc.	7%	47%	32%	31%

Deductions from Tables of Percentages and Pl. III.

Pearl Blue as well as white is more abundant in L. Erie, but the Upper Ohio has more shades of Light Pinkish Lilac. Pink, however, is a color comprised to large extent in Lake Erie shells, while pale grayish blue violet is largely represented in the Ohio.

In the Upper Ohio Drainage:

Pinkish colors predominate in the Allegheny Tribs., but blues in the rivers.

There is less pink in the Ohio than in the Monongahela, while white is not present in the tributaries of the latter. Pale Grayish Blue Violet seems characteristic of the Beaver Tribs. as a whole, while there is less pearl blue in the Ohio than in the Allegheny, but more white. A fading out is seen going down stream in the Allegheny, Monongahela, and Shenango Rivers as well as in the French Creek. Characteristic stream colors are;

Light Pinkish Lilac to Pearl Blue in the Allegheny, Pale Grayish Blue Violet in French Creek, white with a Light Pinkish Lilac tinge in Conewango Creek.

In Lake Erie:

Light Pinkish Lilac predominates at La Plaisance Bay, while a Lighter Pink represents Cedar Point. Presque Isle is apparently between the two with regard to color, in this respect resembling the Maumee Drainage. In this as well as in other species, characteristic colors not mentioned for any given locality are obtained from Pl. III.

Pale Persian Lilac is a typical color for shells from Conneaut Lake, while a more pinkish variety of this—pale pinkish lilac—is

characteristic of Chautauqua Lake.* Greater uniformity of nacre color was found in this than in any other species, a fact somewhat associating itself with the ubiquitous distribution of the species.

Observation on Sex Correlative Coloration, etc. (94 shells).

Males—Pinkish lilac, and apparently a greater proportion of white.

Females—Pale grayish blue violet—slightly more pearl blue.

12.—*Lampsilis ovata*

SIMPSON	RIDGEWAY
Silvery	White
Bluish white	Pearl blue, Pale Grayish Blue Violet
Pink	Light Pinkish Lilac, Pale Purplish Vinaceous.

Distribution of Colors as a Whole in the Upper Ohio Drainage and Lake Erie. (214 shells).

Pearl Blue, etc.	20%
White, etc.	20%
Light Pinkish Lilac, etc.	30%
Pale Grayish Blue Violet, etc.	11%
Pale Purplish Vinaceous, etc.	19%

Distribution of Colors as a Whole in Upper Ohio Drainage. (188 shells).

Pearl Blue, etc.	19%
Light Pinkish Lilac, etc.	25%
White, etc.	19%
Pale Grayish Blue Violet, etc.	19%
Pale Purplish Vinaceous, etc.	18%

Distribution in Upper Ohio Tribs., etc.

	Alle'ny Tribs.	*Alle'ny River*	*Ohio River*	*Ohio Tribs.*	*Beaver River*	*Beaver Tribs.*
Pearl Blue, etc.	20%	22%	14%	10%	35%	22%
Light Pinkish Lilac, etc.	25%	24%	34%	41%	4%	40%
White	20%	22%	25%	13%	16%	16%
Pale Grayish Blue Violet, etc.	17%	15%	12%	25%	16%	15%
Purplish Vinaceous, etc.	18%	17%	15%	11%	19%	7%

Distribution of Colors as a Whole in L. Erie, (26 shells).

Pearl Blue, etc.	24%
Light Pinkish Lilac, etc.	23%
White, etc.	22%

* My observations on all lake specimens of this species correspond with those of Baker concerning it in Oneida Lake, N. Y. Baker, F. C., The Relation of Mollusks to Fish in Oneida Lake, Tech. Pub. No. 4. N. Y. State College of Forestry, Syracuse, 1916, p. 41.

Pale Grayish Blue Violet, etc.....13%
Pale Purplish Vinaceous, etc.....17%

Distribution in Lake Erie—Localities, and Chautauqua Lake.

	La Plaisance Bay	*Cedar Point*	*Presque Isle*	*Chautaugua Lake*
Pearl Blue, etc	25%	24%	25%	40%
Light Pinkish Lilac, etc	25%	32%	42%	35%
Pale Pinkish Vinaceous, etc	37%	33%	13%	25%
Pale Grayish Blue Violet, etc	12%	11%	20%	

Deductions from Tables of Percentages and Pl. III.

Pearl Blue and White are most abundant in L. Erie and there is less Pinkish Lilac or Purplish colors, as well as more Pale Grayish Blue Violet are most peculiar to the Upper Ohio drainage.

In the Upper Ohio Drainage:

The rivers have more Pearl Blue and White than the tribs. but less Light Pinkish Lilac and less Pale Grayish Blue Violet. General shades of Pinks and Pearl Blues are about evenly distributed throughout this drainage. About the same percentage of blues exists in the Allegheny and Beaver Drainages, while White is most abundant in the Ohio,—apparently an outstanding exception to the general rule. Fading is seen going down stream in the Allegheny, Ohio, Shenango, and Little Beaver Rivers. Characteristic stream colors are best indicated in Pl. III.

In Lake Erie:

Here white and pearl blues are practically equivalent. Most of the Light Pinkish Lilac colors are at Presque Isle Bay; Pale Purplish Vinaceous in La Plaisance Bay; while Cedar Point has more purplish colors than Presque Isle, it has less than La Plaisance Bay.

Pearl Blue predominates in Chatauqua Lake.

Observation on Sex. Correlative Coloration, etc. (84 shells).

Males may either be white, pinkish lilac or pearl blue.

Females are purplish vinaceous.

VI.—Conclusions.

1. In certain species, (as may be inferred from the table dealing with the distribution of colors as a whole), there exists a wider range of variation of nacreous color than is indicated by standard specific descriptions.

2. In practically all the species dealt with, a change in nacreous color is observed going down stream from the headwaters to the

mouth. The usual tendency is for the nacreous color to considerably lighten or become bluish.

3. The shells of L. Erie have a greater proportion of blues among them than the corresponding shells in the Upper Ohio Drainage. and Maumee Drainages. The shells of Conneaut and Chautauqua Lakes have the same relation.

Other conclusions, not however as completely substantiated as those given above, but still so evident from the present data as to deserve mention are:

1 Each drainage leaves its own imprint on the shells collected from it in the form at least of an associated peculiar tone of nacre color. (This has already been observed with regard to other physical characters). While the same "relative colors" may be present in different drainages, these are usually distinguished when necessary by varying proportions of other colors.

2. As a rule, the color distinction may be carried so far as to say tentatively at least, that certain shades of nacre color are characteristic of certain localities in a given body of water. While as observed in the chart, this is best observed in the case of Presque Isle shells, ample verification is obtainable in shells from the Upper Ohio Drainage.

3. So far as we may consider results obtained from a small number of shells in many cases, sex correlative coloration seems to be associated with nacre color.

VIII.—Suggestions as to Causes of Facts.

Introductory remarks embody the writers' comments on the first of these conclusions. Any plausible explanation of the second would seem to be found in the physical and chemical conditions under which the shells live. A summary of the physical and chemical conditions present in the Upper Ohio Drainage and L. Erie has been given. Perhaps that physical condition most applying to the problem of nacreous color is the warmer temperature of the water in the former, for it has been seen that as a rule, Upper Ohio shells possess more pigment than those of L. Erie. Pigment is the result of chemical reaction, and chemical reactions in general are increased by the amount of heat.

Wilson and Clark, (18, 19) were inclined to associate with the fading out of the nacreous color of *Elliptio* an abundance of lime, and, (conversely), the want of humic acid in the lower stretches of

the stream." Humic acid" seems to be an indefinite chemical term applied to several acid compounds having their origin in the decay of vegetable matter. It is commonly supposed to impart its straw colored to deeper hues to the streams in which it is found. Such a stream is the Shenango R. fed by Pymatuning Creek which in turn drains a swamp. For the reason that forests with their residual humus are, under present conditions at least, most abundant near the headwaters of streams, it may be reasonably supposed that Humic Acid, if any, is most abundant there. As an acid, it must tend to be neutralized later in those streams having an abundance of lime, ($CaCO_3$), and consequently disappear, for analyses of the water in various parts of the Upper Drainage where the shells were collected (6,10), show that there is an increase in the amount of lime present and alkalinity in general going down stream, with a converse reduction, it may be assumed, of any acidity. Faussek, (2), in studies with marine pelecypods came to the conclusion that water containing acid promoted the formation of pigment, while he believed that light played no part in this process. List, (11), another observer was inclined to credit the importance of light as a factor in pigment formation. As the headwaters are freer from silt than those of the lower stretches, we have according to these investigators, more ideal conditions for the production of pigment there than further down stream, where as a matter of fact it is less abundant. In this behaviour of nacreous color of Najades in upstream regions we have a rough analogue to that of the reaction of litmus to acids snd alkalies. Further, the water of L. Erie differs from that of the Upper Ohio Drainage and its lower regions in possessing a greater amount of lime and general alkalinity, especially to note after any humic acid entering the lake has been neutralized. L. Erie waters also contain certain chemicals such as magnesium sulfate and chloride, which are not found, at least in similar quantity, in the Upper Ohio Drainage. Now L. Erie shells have been found to have greater percentages of Blue. This corresponds with the reaction of litmus toward alkaline solutions.

A second analogous example and one more closely related to the factors concerned in the case is the behavior of iron compounds toward CO_2 (13). It is known that Humic Acid attacks the iron oxides, (Fe_2O_3) which color soil red or yellow, and reduces these compounds to ferrous oxide. Ferrous oxide then unites with the CO_2 omnipresent in soil water, forming ferrous carbonate, a colorless

compound. As the result of these interactions the ground beneath humus deposits is usually found bleached. Clays, originally red or yellow, may become black, green or blue from the organic matter contained and from the effects of this process. When clay is burned, the organic matter and ferrous carbonate contained is oxidized, and red brick is formed for whose red color the iron oxide is responsible. Now analyses of the shells of 4 common species of Najades furnished through the courtesy of the Commissioner of Fisheries, Washington, D. C., show that the differences in composition between them is greatest and most marked in the content of organic matter, iron, alumina and phosphoric acid. The first three of these are important constituents of soil, and are known to be responsible for the colors of many minerals. The greater rapidity of current, rapids, etc., of the headwaters of streams makes for their greater oxygenation, and this available oxygen may so react with these minerals of the shell as to produce the deeper colors characteristic of the headwaters in a fashion corresponding to the processes described. Further down stream, silt and slow moving waters as well as other conditions may tend to inhibit the oxidative process, and, similarly there may follow a greater inclusion of organic matter in the shell, possibly from the silt itself, resulting in other than the red or yellowish colors allied to iron oxide. A relatively similar situation is found in L. Erie, which has less silt but lighter colored shells. The lighter colors of L. Erie shells may be closest related to the degree of alkalinity of the water. As the natural conditions of the Upper Ohio Drainage are also largely similar to those of the streams draining into L. Erie, a similar explanation may be assumed for their colors. Another alternative hardly consistent with the above facts is that the concentration of humic acid toward the mouth of the stream becomes sufficient to bleach or lighten the colors whose basis is iron. The improbability of this latter becomes clearer when it be remembered that lime also increases in amount going down stream. A more reasonable explanation is that CO_2 whether of the soil water or released from combination by the interaction of humic acid and lime, attacks the ferric or ferrous oxide, already present in the shells and produces ferrous carbonate, which colorless compound may be responsible for the lightening of hues observed. Such an explanation at least embraces most of the physical and chemical conditions known, and is certainly applicable to the many curious facts concerning the nacreous color known

to experienced collectors. With regard to the part iron plays in the coloration of the shells of these animals, it is suggestively recalled that it is the basis of many animal and plant pigments such as haemoglobin, bilirubin, chlorophyll, etc.

Speculations here may be unbridled as in other fields and the only thing to qualify it is experimental proof. It may be noted that in many organisms strong production of pigment has been considered evidence of progressive metabolism and sometimes associated with "femaleness" in particular. In other organisms beside the Mollusca it has been also associated with amount of oxygen present, and under the physical conditions the waters of the Upper Ohio are as a whole better oxygenated than those of L. Erie. Some of the observations bear out in part observations on another group of the Mollusca, the Chitons, where Crozier, (1) has found a more brilliant coloring of the soft parts associated with the "female" condition, believing it merely to be the result of a "metabolic accident." From the evidence given, there may be reason to state that the nacreous "ground color" of shells, from which all colors are produced by modification, is a Pearl Blue or "whitish" hue. Dr. A. E. Ortman in an unpublished paper which confirms observations of several other investigators, has shown that the shells in the headwaters of streams are usually smaller and more compressed than the same species in the lower stretches, where they have become more highly inflated. Some factor in the environment may thus inhibit the full physical development of the shell in the headwaters, but its racial metabolism, evident in greater development down stream, may find an outlet in the production of pigment, a variation hardly as harmful to it as increase in size and inflation would be in the swift streams of the headwaters. Against the above we have the check of Koifoids observation, (9), that the plankton elements on which these creatures feed increase with the temperature, and are more abundant in the lower stretches of the stream where there is more silt, and where the shells are more highly inflated. Finally it must be remembered that in so far as outside conditions are concerned, the nacre throughout life is protected by the greater thickness of the shell.

In the preceding, endeavor has been made to consider the more plausible factors responsible for variation in nacreous color among the Najades. If a theory of "progressive metabilism" in organisms

be held accountable in any way for variation in the nacreous color of Najades, a factor of possible connection is that of the age of the mussels. In obtaining any light upon the relation of the nacreous color and the age of the animal, a difficulty which presents itself is the accurate determination of the latter. Isely* who has probably made the most extensive study of the growth of Fresh Water Mussels, states that ordinarily the prominent rings of the shell are presumably winter rings, (delayed growth), and therefore each may represent a year of the animals life. However, rings may develop as the result of unfavorable conditions such as water shrinkage, temporary stranding, etc., and at any time of the year. Moreover, the rate of growth is variable for individuals of a single species in the same stream apparently depending on conditions of food, oxygen etc. . . . Growth may also slow down after sexual maturity. All these unfavorable conditions probably act to some degree on shells in the Upper Ohio Drainage. However at the time the color data was recorded, the writer estimated the age of these and those from L. Erie by counting the rings of greatest prominence, which Isely indicates are presumably the winter rest rings. Here it may be remarked as already shown elsewhere,(3), that the shells of L. Erie are under more stable conditions, and greater confidence may be placed in such a method of estimating the age of them. This latter fact was the basis of a check in the following procedure.

There was only the task of rearranging the different recorded colors by classes of the estimated age, and this being done to see whether association was evident between the recorded hues and the estimated age. As insufficient space prevents reproduction of the tabulations thus secured, it can only be stated that all of the colors of all species were found to be distributed through all ages rather than being peculiar of certain ones. Certain generalizations are worthy of note,† that as a rule deeper colors in all species fade

* Isely, F. B. "Experimental Study of Growth and Migration of Fresh Water Mussels" Bureau of Fisheries Document, 792 (1914)

† Thus with age, (using terminology of Simpson); in *Fusconaia*, the percentage of whites and salmons increase, rose tints decrease; *Amblema*, the bluish colors tend toward lilac shades; salmon, straw, and white increase in *Elliptio*, purples become lighter as also in *Proptera* and *Paraptera;* the reds fade out in *Pleurobema* and the salmons and buff in *Symphnota*, when the pinkish hues become more prominent. Bluish white increases in *Anodonta*

with age, most of them tending to revert back to the "pearl blue or whitish" ground color. Similar treatment of L. Erie shells apart from those of the Upper Ohio corroborate this finding. But to be considered with such a generalization, is the fact that very frequently large nos. of shells of different ages from the same locality show an almost uniform nacre color.

IX. Relative Variation in Nacreous Color in the Species Dealt With.

The shells were so unevenly distributed with regard to localities, that it was impossible to determine those places where the greatest amount of nacreous color took place. Some idea may be obtained from Pl. III. In an effort to make a balanced determination of the relative variability of nacreous color among them a rough and arbitrary comparison was taken by dividing the number of "relative colors" observed in each shell by the number of that species examined. Rough as the writer feels his methods to have been in exploring this uncharted field, it seems that within the limits of this investigation that the larger number of shells is apparently associated with less variation in nacre color. At the same time, these results are hardly fair for those species represented by a small number of specimens. Results from this method show the relative variability of the shells to be as indicated in the following table.

	No. of Relative Colors Taken	*No. of Shells*	*Factor Calculated*
1. *Eurynia recta*	29	54	.53
2. *Proptera alata*	26	55	.47
3. *Paraptera fragilis*	23	53	.40
4. *P. obliquum coccin*	53	263	.20
5. *Amblema plicata*	35	185	.18
6. *Anodont ferrussacianus*	8	45	.17
7. *Anodonta grandis*	19	119	.16
8. *Fusconaja flava*	40	273	.14
9. *Lampsilis ovata*	31	214	.14
10. *Elliptio dilatatus*	76	561	.13
11. *Symphynota costata*	19	68	.13
12. *Lampsilis luteola*	26	289	.09

A similar study of variation in Epidermal Color in the animals is expected to appear in a later number of this publication.

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and *Anodontoides*, while the purples tend to disappear. *Eurynia*, *L. luteola*, and *L. ovata* appear to retain their vivid colors to later age than the rest of the species, but all of the latter tend to revert to "bluish-white."

Sources of Error.

The Ridgeway Nomenclature was used carefully following directions given in it. It may well be urged that the sense of color is so varied in its development among huminity that results of this kind may not have the same significance for a great number of those interested in these problems. But the same criticism could be applied to the ornithologist who uses the Nomenclature. The writers confidence in his own observations is largely based on the fact that U. S. Army tests have shown his sense of sight to be normal in every respect.

It is also true that at times the mussels migrate from place to place in the same stream and from the river into the tributary. Where a small number of shells were used in making a comparison, this might have some effect on the results obtained, but as the evidence of most observers is that migration is comparatively rare among them, this can have hardly any effect on the general impressions this paper has hoped to convey.

Washington and Jefferson College,
Washington, Pa.

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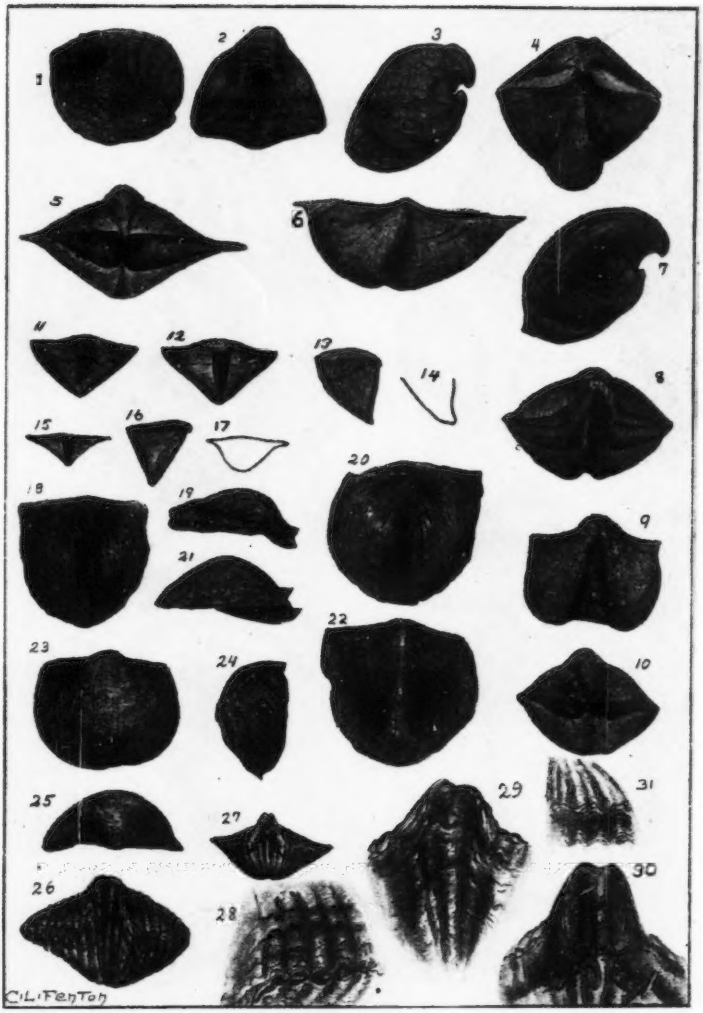

PLATE II.—FENTON ON THE HACKBERRY STAGE.

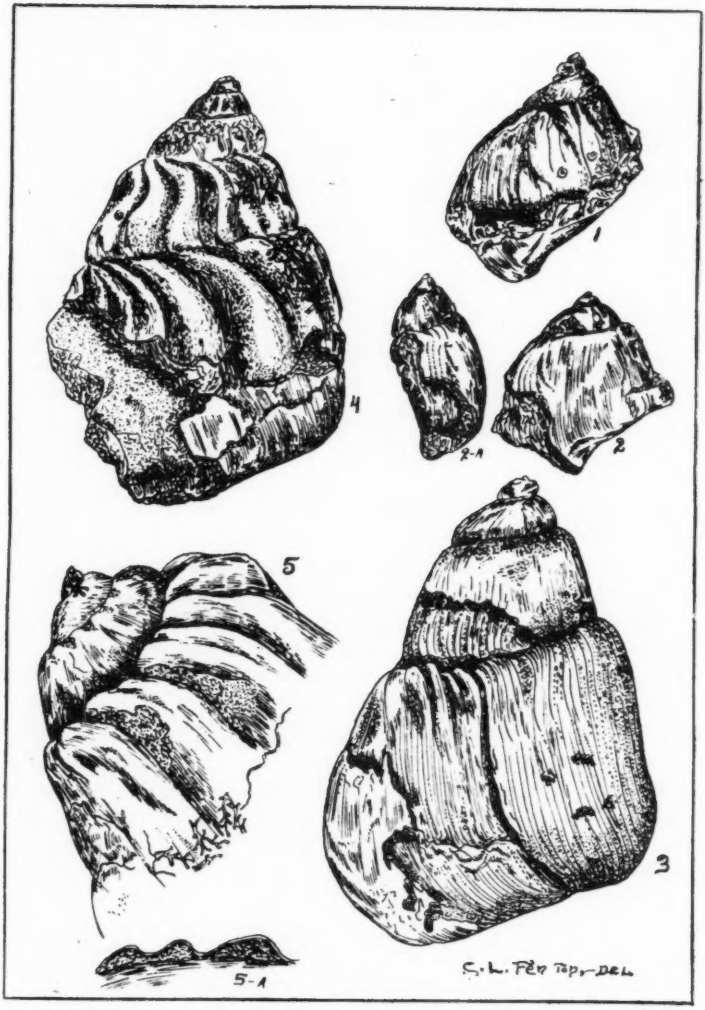

PLATE III.—FENTON ON THE HACKBERRY STAGE

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Dr. Joel Lunell.

A great loss to the science of taxonomical Botany was felt when Dr. Lunell passed away at Leeds, North Dakota, on Thursday, May 27, 1920. Living nearly all his life in a region which botanically was a fertile field for investigation scarcely worked up in a painstaking and orderly way, he brought to his avocation a love of nature, a clear discerning judgment of specific differences, and well trained classical education. He was born in an old castle, "Kalmar Fort," a beautiful place facing the Baltic Sea which was built about the year 1000. His early schooling was finished with unusual honors. His studies in medicine was finished at the great and historical University of Upsala where Linnaeus himself was professor over a century previous. The remarkably broad education in medicine, classics, natural science which he possessed was augmented by a keen appreciative love of music as well as proficiency in modern languages. During his six years of study at Upsala he spent his vacation as tutor in latin and music. Among the books he wrote and translated about this time were some in branches as varied as the following. He published a Physicians' Dietary Cook Book, and a Cook Book on Mushrooms, He translated into Swedish, his native tongue, from German, French, and English the following works. *Physiologie de Got*

by Brillat, *The Prince and the Pauper* Savarin, *Innocents Abroad*, by Mark Twain, *What Shall We Do?* by Tschernyschevsky. After finishing at Upsala he took a post graduate course at the Carolyn Institute at the University of Stockholm. In 1888 he came to America and became an associate to Dr. Fleisburg at St. Paul but longed for the frontier life of the new country and settled at Willow City, North Dakota, then a primeval town of a few board houses. Being the only physician in the whole county his zeal for his profession kept him so busy travelling around to help the sick that he was often eighteen to twenty hours without food. He was during these strenuous times also president of the village council, alderman, coroner, U. S. examining physician, and postmaster.

Overwork forced him to relax for vacation from so many numerous pursuits; he left several times but always came back after a few months. In 1894 he came to Leeds where he held office as mayor, alderman and coroner besides his duties as physician.

Dr. Lunell devoted his leisure time to the study of the flora of his region. He published some of his investigations in the Botanical Gazette and published several numbers of *Contributions from the Leeds Herbarium*. Most of his later writings appeared in the *Midland Naturalist*, notably a number of diagnoses of new species and a list of the plants of North Dakota. Unprejudiced by codes as a man of his broad classical training he throws aside any leaning to nomenclature codes of present expediency and adopted system of absolute priority of names for this list. He collected a large herbarium (30,000 plants) the specimens being remarkably well mounted, a collection which is scarcely without a peer in perfection of technique, exactness and completeness in every detail. The passing away of one whose love for nature was observation and whose pursuit of knowledge of the plants of his region was an unselfish contribution to science leaves a gap that will be hard to fill. The following notice in the *Leeds News* of June 3, 1920, brings out other features of his life not already touched upon.

A short time ago we were surprised to hear that Dr. J. Lunell was ill at his home and that his illness was considered serious. Always an active man and accustomed to be about daily it was hard to believe that we had seen him on the street one day and that he was seriously ill the next. Such, however, was the case. On Friday the news that he had passed away on Thursday night was quickly spread through the city. Another pioneer had passed to his reward.

With the passing of Dr. Lunell this generation loses one of nature's

noblemen. A lover of the great out-of-door and deeply interested in botany he mingled with flowers all his life, and the study of plants and music was his chief delight. His was a sensitive nature, easily hurt, but never did he allow hatred to enter his heart. Kind hearted and sympathetic, he felt deeply the pain and sorrow of those in trouble. Those who knew him best knew him as a man who followed Christ's teachings in all that he did, and loved him for his kindly, sympathetic nature.

Joel Lunell was born in Kalmar, Sweden, March 30th, 1851, and spent his boyhood days there. His father was Doctor of Theology and Philosophy and pastor of the Lutheran State Church, in which creed Joel Lunell was baptized. As he grew to manhood many hours were spent at the great pipe organ in the church and his knowledge of music gave him daily pleasure in later years.

At the age of eighteen he entered the university at Upsala, Sweden, to study philosophy and medicine.

He was married at Kalmar, Sweden, in 1884, to Miss Emma Swenson. In 1888 they came to America and settled at St. Paul where he was associated with Dr. Fleisburg. Later he moved to Willow City, where he practised his profession. In 1894 he moved his family to Leeds and has since made his home here.

In the early days of his career he worked so unceasingly among the sick that his health was broken, but in spite of this fact he still carried on. During the flu epidemic of 1918 he did his bit with the other and younger physicians, attending cases night and day until the danger had passed.

Besides keeping up his medical practice Dr. Lunell compiled a herbarium of over 30,000 specimens of plant life, including plants from all over the world. During the past thirteen years he has written botanical articles for the *American Midland Naturalist*, published at Notre Dame, Indiana.

Funeral services were held Monday afternoon from the Lutheran Church and interment made here. He is survived by his wife, six children and a brother.

"Waterfowl in Nebraska."

This very interesting and informing paper forms Part I. of Bulletin 794 of the U. S. Department of Agriculture. The following are the contents:—Introduction; Effect of Federal Protective Laws; Future of Waterfowl in the Sandhill Region; Natural Enemies; Hunting Grounds; Waterfowl Hunting in the Autumn of 1915; General Description of the Sandhill Region; Annotated List of Birds; Game Birds; Nongame Birds.

Seldom have I enjoyed a more interesting article on bird life than the one under consideration. And an important element of this interest is the description of the Sandhill Region where Dr.

Oberholzer made his observations. I think this large and unique territory is comparatively unknown, at least to that portion of the community that is not especially devoted to the sportsman's gun. But quite apart from the attraction that a hunter would naturally have for such a paradise of game birds, the Sandhill Region of Nebraska should be known to all Americans. There is probably no other similar territory that can approach in their vast extent and unique character the Sandhills of Nebraska.

As the contents of Dr. Oberholzer's paper indicate, he has made a very careful study of the waterfowl of the Sandhill Region of Nebraska. The reading of his article quite makes the bird lover envy the writer the excellent opportunity he had to study waterfowl. Most observers, unless they live in a favorable place, near a quiet lake or river, can not become acquainted with water birds. This has been my own experience, and I often regret that my home is not located where the study of waterfowl is possible. Dr. Oberholzer's contribution is, then, of great interest to the student of general ornithology, and will, no doubt, be universally appreciated.

A feature of Dr. Oberholzer's article that calls for special mention is the manner of treating his subject. Not too technical for the general reader, and still of genuine value to the special student or the hunter, his paper is a model of attractive writing on ornithology. The great detail (which shows minute observation) of the article can not be too highly commended. The author's work has been so well done that the reader feels grateful to him for the knowledge and pleasure that were made possible by the perusal of this fine production. It is to be hoped that many more similar opportunities will be afforded Dr. Oberholzer to visit regions where waterfowl are abundant. This seems to be a phase of ornithology in which the doctor should specialize, for his present paper points unmistakably to his ability to cultivate this field most profitably.

BROTHER ALPHONSUS, C. S. C.,
Notre Dame, Indiana.

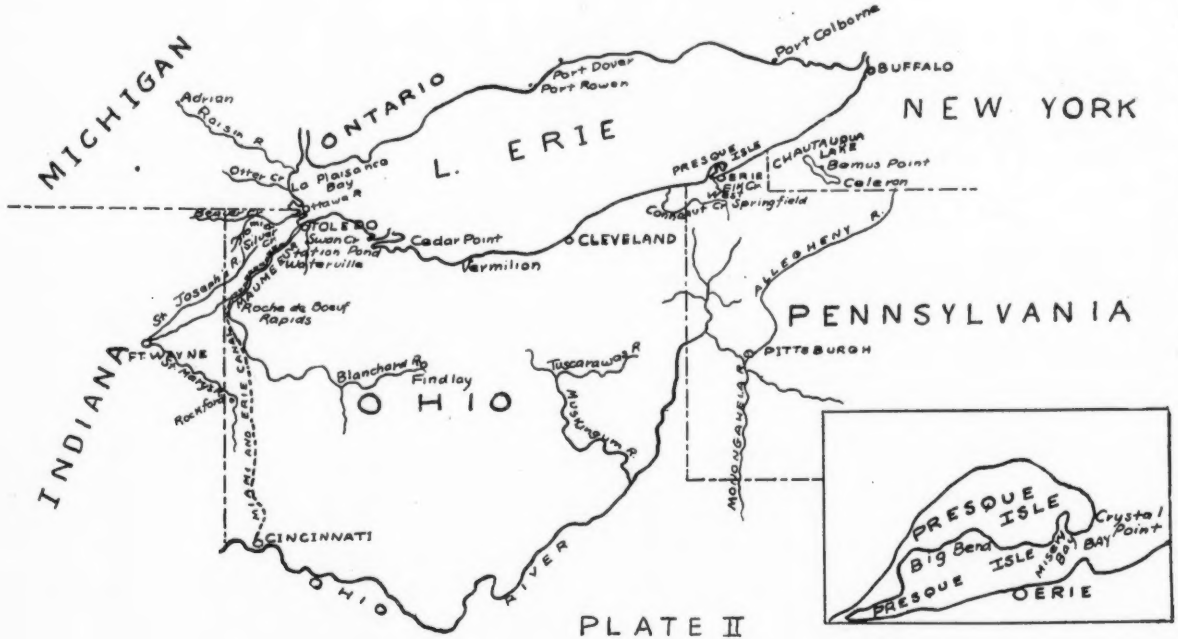

PLATE II

MAP OF LAKE ERIE AND ADJACENT REGIONS

SHOWING LOCALITIES CONSIDERED

PLATE II.—GRIER ON VARIATION IN NACREOUS COLOR OF CERTAIN SPECIES OF NAIADES.